



# NASA Office of Technology Transfer

## John C. Stennis Space Center

### Next Generation Scene Simulation Software May Help Expedite Hyperspectral Imagery Processing

*A physics-based scene simulator of hyperspectral imagery*



***MCS**cene color composite simulation of a scene containing significant 3D terrain structure and an artificial disc-shaped cloud*

*MCS*cene is a physics-based scene simulator developed by Spectral Sciences, Inc., of Burlington, MA, under a NASA Small Business Innovation Research (SBIR) program contract with Stennis Space Center. Development of *MCS*cene was motivated by the need for an accurate, robust and efficient means of algorithm validation for the processing and analysis of hyperspectral imagery. The prototype, delivered to NASA Stennis in May 2002, has already proved beneficial to the NASA Earth Science Application Directorate (ESAD) program at its Verification and Validation range.

*MCS*cene is a physics-based scene simulator of hyperspectral imagery. It delivers first principles treatment of the full radiative transport problem, calculating molecular absorption, atmospheric and aerosol scattering, cloud scattering and reflection from three-dimensional terrains.

Hyperspectral imagery has great utility in a variety of commercial and government applications including, but not limited to, target detection and identification, precision agriculture, mineral exploration, forest management, ocean resource mapping and surface pollution detection. The quality of retrieved surface spectral reflectance from hyperspectral imagery depends on the accuracy of atmospheric compensation and surface retrieval algorithms. However, the use of field measurements for algorithm validation is expensive, time consuming and impractical for data collection over the full range of atmospheric and surface conditions required to fully test the algorithms. Currently, there is no commercial software

#### **HOT** Points

- **Physics-based scene simulator**
- **Accurate, Robust and Efficient**
- **Provides high fidelity, highly characterized hyperspectral imagery data**
- **Computed in Hypercubes**
- **Applications include: target detection, precision agriculture, mineral exploration, forest mgt. and surface pollution detection**

application available with this capability. *MCS*cene was developed as a source of high fidelity, highly characterized hyperspectral image data that can serve as substitutes for and supplements to field validation data.

### WHY *MCS*cene IS IMPORTANT

Because *MCS*cene is based on a Direct Simulation Monte Carlo (DSMC) approach for modeling 3D atmospheric radiative transport as well as spatially inhomogeneous surfaces, including surface Bi-directional Reflectance Distribution Function (BRDF) effects, it is important to first understand the importance of the DSMC method in the realm of hyperspectral imagery.

Subtle features or small temporal changes in the surface spectral reflectance are often the markers of interest for commercial hyperspectral imagery applications, such as monitoring for crop stress or searching for valuable mineral deposits. Finding these spectral markers is challenging because of the corrupting influence of the atmosphere on the true surface spectrum. Virtually all-scientific and commercial applications of hyperspectral and reflected light are in the visible-near infrared (VIS-NIR) spectral region, typically spanning the 400-2500 nm region. The influence of the atmosphere in this range is significant even in the case of a clear sky with moderate visibility. Compensation for these effects is complex because they arise from a variety of different sources, such as molecular absorption, aerosol and molecular scattering and aerosol attenuation. The DSMC method is ideally suited to fully treat the spectral-spatial complexities of the simulation problem; it has the ability to handle complex geometries and allows the interactions of trial photons with the atmosphere and surface to be described with complete generality. It also enables upgrades and additional physical photon interaction models to be easily integrated into the simulation.

The well-known drawback to the DSMC approach is the very large number of trial photons needed to achieve an accurate result, thus leading to unacceptable computational times. However, recent advances in the processing speed of computer chips combined with practical and affordable parallel processing software for PC's have helped to overcome this limitation to the DSMC approach. *MCS*cene has proved to be a practical prototype DSMC HSI simulation code. It has demonstrated its utility by simulating the effects of varying sensor altitude, atmospheric visibility and spatial adjacency on an atmospherically corrected HSI surface reflectance data cube. Thus, *MCS*cene affords a practical means to extend the utility of costly field data by accurately simulating the effects of varying sensor, atmospheric and illumination conditions on real data.

The success of the prototype simulation code has benefited a number of other related projects at Spectral Sciences. For example, it has provided the foundation for an improved adjacency compensation algorithm in Spectral Science's atmosphere correction code (ACC), a MODTRAN4 radiation transport-based atmospheric correction code developed by Spectral Sciences and the Air Force Research Laboratory for analysis of hyperspectral radiance data. It has also enabled a rigorous validation for the DISORT multiple scattering algorithm as implemented in MODTRAN. Finally, the simulation is being used to develop and evaluate a fast VIS-NIR cloud-masking algorithm under the ACC upgrade activities.

### TARGET MARKETS

The commercial product of *MCS*cene is computed in hypercubes, which will be used by hyperspectral imaging researchers for sensor and algorithm development and validation for the multitude of hyperspectral and multi-spectral satellite and aircraft sensors under development by Department of Defense, NASA, and commercial companies. These sensors span a diverse range of applications such as target detection and identification, precision agriculture, mineral exploration, forest management, ocean resource mapping, and surface pollution detection. There is also potential application to climatological research on atmospheric radiation budget assessment via coupled analyses of ground, aircraft and satellite based sensor data. The simulation software will also be provided to NASA Stennis for incorporation in its data simulation programs for scientific exploitation of hyperspectral data.

### FUTURE OF *MCS*cene

Spectral Sciences and its commercial partner, Research Systems, Inc. of Boulder, CO, are working to get *MCS*cene ready for commercial release and performing market analysis for the commercial product.

Proven success of the package, such as with the NASA Stennis V&V range, has allowed Spectral Sciences to win other government contracts to extend the technology to other uses. The company is in its second year of a Phase II SBIR with the National Imagery and Mapping Agency (NIMA) to, in part, extend *MCS*cene to littoral regions, including simulation of transmission through water and reflection from water surfaces. It is also working on a Phase II SBIR with the US Air Force to extend *MCS*cene to treat radiation at wavelengths through the long-wave infrared. Additionally, Spectral Sciences was awarded an STTR contract to adapt *MCS*cene for the simulation of LIDAR in battlefield scenarios.

### WHY SBIR

"This product would not be possible without the NASA SBIR program," said Fritz Bien, Spectral Sciences' president. The SBIR program provides an excellent avenue for small businesses like SSI to develop commercial products," said Steven Richtsmeier, principal investigator for the program. "Working with the people at NASA was extremely beneficial because it allowed us to tailor *MCS*cene as it was being developed for the kind of customer we want to reach with a commercial product."

### Points of Contact

- NASA Office of Technology Transfer  
Stennis Space Center, MS  
PH – 228-688-1929  
Web – [technology.ssc.nasa.gov](http://technology.ssc.nasa.gov)  
E-Mail – [technology@ssc.nasa.gov](mailto:technology@ssc.nasa.gov)
- Spectral Sciences, Inc.  
Burlington, MA  
PH-781 273-4770  
E-Mail-[fritz@spectral.com](mailto:fritz@spectral.com)